THE INFLUENCE OF INTENSE ELECTRIC FIELDS UPON THE ELECTRON EMISSION FROM TUNGSTEN

BY

JOHN HERBERT LADD

B.S., University of Illinois, 1940
M.S., University of Illinois, 1942

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN
CHEMISTRY IN THE GRADUATE SCHOOL OF
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INTRODUCTION

Previous studies of the influence of electrostatic fields upon the thermal emission of electrons have been made in this laboratory by Seifert and Phipps,[1] and by Turnbull and Phipps.[2] The present study was an attempt to redesign the apparatus previously used, preparatory to exploring the influence of electric field intensities greater than 0.6 megavolt/cm upon the thermal emission of electrons from a pure tungsten surface.

DISCUSSION OF RESULTS

The diode was redesigned in order to attain a higher field intensity at the cathode surface. A change to spherical symmetry was considered, but it was decided to retain the cylindrical symmetry of previous diodes. While accurate absolute measurements would not be feasible with either type of symmetry, it was thought that the cylindrical symmetry would allow more precise measurement of cathode area and of field intensity. The laboratory lacked an induction heater to outgas massive diode elements. This lack prevented the use of a sealed-off diode of more conventional design, and forced the use of a continuously pumped diode with anodes formed by evaporation of a tungsten film onto the inner wall of the diode envelope.

Accurate absolute measurements of electron emission were not feasible primarily due to roughness of the cathode surface, to anisotropy of tungsten, and to the difficulty of determining the true absolute temperature of the cathode. Precise relative measurements, however, were possible. The design of the diode and of accessory electrical units was based upon an analysis of experimental errors. The instabilities of the electric circuits and the errors of measurement were consistent with a precision of $\pm 0.1\%$ in the value of the anode current.

The cathode heating current was held constant to within $\pm 0.006\%$ by an electronic filament supply unit with conventional current-stabilized output. The value of the filament current was measured to a precision of $\pm 0.1\%$. The cathode-anode potential was supplied by an electronic unit with output continuously adjustable from —4 to —2300 volts. For any potential of magnitude greater than 125 volts the output of the unit was stable to within

$\pm 0.1\%$. The cathode-anode potential was measured with a precision potential divider to within $\pm 0.1\%$. This latter measurement was ordinarily made within ten seconds of measuring the anode current. An electronic current-stabilized filament aging unit was also used.

For precise measurement of the anode current, the anode was divided into three sections. The two end sections served as guard rings and were grounded. The current to the center anode was calculated from the measurement of the potential drop across a precision resistor in series with the anode. The anode circuit was so arranged that the center anode was at ground potential during the measurement.

Preliminary measurements were made at electrostatic field intensities up to 0.54 megavolt/cm. The prime source of experimental error was lack of concentricity of cathode with anodes. The eccentricity increased with increasing field intensity. Above 0.06 megavolt/cm the filament vibrated erratically with amplitude roughly a direct function of the applied field intensity. The errors due to eccentricity of the diode were great enough to mask completely the small periodic deviations from the Schottky line which were observed by Seifert and Phipps,[1] by Turnbull and Phipps,[2] and by Nottingham.[3] The diode design used in the present study made centering of the filament more critical than was the case with diodes previously used in this laboratory. A redesign of the diode must be undertaken in order to simplify adjustment to concentricity.

An exact expression for the average field intensity at the cathode surface of an eccentric diode was derived in detail from fundamental electrostatic theory.

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VITA

The writer was born in Kewanee, Illinois, 6 September 1918. He graduated from Kewanee High School in 1936. He attended the University of Illinois, 1936 to 1940 on a Scholarship, graduating with a B.S. in Chemistry with Highest Honors, June 1940. At that time he was also commissioned a Second Lieutenant in the Chemical Warfare Reserve, having completed four years of ROTC training. He immediately entered the University of Illinois Graduate School, serving half-time as a Teaching Assistant in Physical Chemistry until he was called to active duty in the Army of the United States, 6 April 1942. In June 1942 he received an M.S. degree.

While on active duty he attended the 3rd Basic and the 10th Advanced Courses at the Chemical Warfare School. He was assigned as a research physicist to the Chemical Warfare Service Technical Command, Edgewood Arsenal, Maryland, from June 1942 until he started his terminal leave in February 1946. He was promoted to First Lieutenant in December 1942 and to Captain in April 1944. He spent the winter of 1942-3 at the Chemical Warfare Service Development Laboratory, Massachusetts Institute of Technology, where he was fortunate enough to be associated with Professor Wayne B. Nottingham, an expert on electronics, photoelectric emission, and thermionic emission. In 1945 the writer was in charge of instrumentation on the CWS "FRED" Project, applying liquid chemical fuels to the assisted takeoff of guided missiles. He also worked on the application of radio tracers in field testing, on the laboratory study of flame thrower fuels, and on the stability of chemical agents, being primarily concerned with the application of instrumentation to chemical problems.

From February 1946 to February 1947 he attended the University of Illinois on a National Research Council predoctoral fellowship. He is married and has one son. He is a member of the American Physical Society, American Chemical Society, Sigma Xi, and Beta Theta Pi.

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